Health Care Computing and the Next Generation Internet

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Initiatives in Health Care Informatics

Advanced Technology Program

Annual Meeting

National Institutes of Standards and Technology

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Historical Perspective on the Internet

- **(D)ARPA investments (Kahn)**
  - **Roberts (BBN) and packet switching**
  - **Kleinrock (UCLA) and first Telnet use**
  - **FTP and Email**
- **Emergence of TCP/IP as standard (Cerf)**
- **LAN developments - Xerox and Ethernet**
- **Creation of domain system**
- **Absorption of BITNET and CSNet**
- **Role of NSF and NSFNet - 1985**

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It's 1978: How many of you would have invested in this company?

Microsoft Corporation, circa 1978

Science and Medicine Discover the Net

- **SUMEX and Rutgers resources in the 1970s**
- **Lederberg article in 1978: "Digital communications and the conduct of science: the new literacy"**
- **Mid-1980s: Wide-area networking implemented at NIH**
- **Federal Networking Council and its FNC Advisory Committee**
- **Debates regarding opening the network to commercial activities**
- **Collaboratory notion emerging in part from the National Academy of Sciences in the 1990s**
- **Rise of the World Wide Web**
  - **Development of HTTP and HTML**

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Federal HPCC Program

- Chartered by Congress in the High Performance Computing and Communications Act of 1991
- Creation of National Coordinating Office (NCO) for HPCC, initially at National Library of Medicine
- Annual "Blue Books" have prominently featured biomedical applications

Participating Agencies

- Defense Advanced Research Projects Agency (DARPA)
- National Science Foundation (NSF)
- Department of Energy (DOE)
- National Aeronautics and Space Administration (NASA)
- National Institutes of Health (NIH)
- National Security Agency (NSA)
- National Institute of Standards and Technology (NIST)
- Department of Education (ED)
- Department of Veterans Affairs (VA)
- National Oceanic and Atmospheric Administration (NOAA)
- Environmental Protection Agency (EPA)
- Agency for Health Care Policy and Research (AHCPR)

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Participating Agencies

- **Defense Advanced Research Projects Agency (DARPA)**
- **National Science Foundation (NSF)**
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- **National Aeronautics and Space Administration (NASA)**
- National Institutes of Health (NIH)
- National Security Agency (NSA)
- National Institute of Standards and Technology (NIST)
- Department of Education (ED)
- Department of Veterans Affairs (VA)
- National Oceanic and Atmospheric Administration (NOAA)
- Environmental Protection Agency (EPA)
- Agency for Health Care Policy and Research (AHCPR)

Five Current Areas of Cross-Agency Coordination

- **High End Computing and Computation (HECC)**
- **Large Scale Networking (LSN)**
- **High Confidence Systems (HCS)**
- **Human Centered Systems (HuCS)**
- **Education, Training, and Human Resources (ETHR)**

See http://www.ccic.gov

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Looking to the Future:
Reliable, High Speed Networking

- **Radiology: transmission and sharing of radiographs, CT and MRI scans, and 3-D reconstructions**

Higher Bandwidth Networks Can
Improve Image Transfer Tasks

Modality	Information Density	Typical Modems 9.6 kbit/sec	ISDN Lines 128 kbit/sec	DSL Lines 384 kbit/sec	T1 Lines 1.536 mbit/sec
CT Scan	5.2 Mbits	9 min	42 sec	13.5 sec	3.3 sec
Chest X-ray	12 Mbits	21 min	1.5 min	31 sec	8 sec

A typical radiologic consultation may require from 10-60 images.   Source: Technologic Partners

Standard Ethernet: 10 mbit/sec
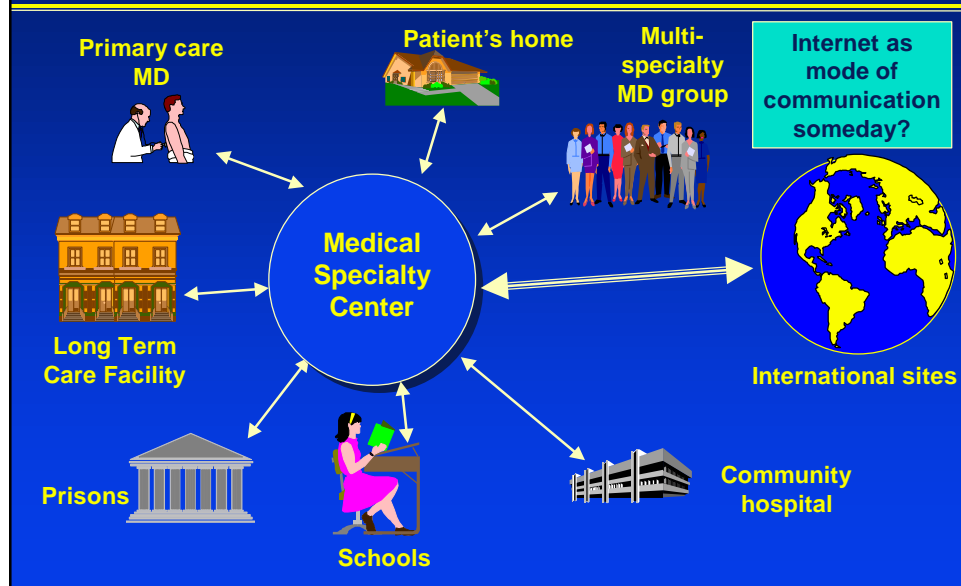**Newer Ethernet Technologies: up to 100 mbit/sec**
Asynchronous Transfer Mode (ATM): even faster....

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Looking to the Future:
Reliable, High Speed Networking

- **Radiology: transmission and sharing of radiographs, CT and MRI scans, and 3-D reconstructions**

- **Telemedicine: Multimedia video conferencing for education, consultation, and collaboration**

The Evolution of Telemedicine

Primary care MD

Patient's home

Multi-specialty MD group

Internet as mode of communication someday?

Medical Specialty Center

Long Term Care Facility

International sites

Prisons

Schools

Community hospital

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Looking to the Future: Reliable, High Speed Networking

- **Radiology: transmission and sharing of radiographs, CT and MRI scans, and 3-D reconstructions**

- **Telemedicine: Multimedia video conferencing for education, consultation, and collaboration**

- **Interactive visualization (e.g., surgery, anatomy)**

- **Remote access to molecular modeling resources**

- **Interactive consumer health information, education, and communication with providers**

- **Addressing the problem of the "last mile"**

Anticipating the Internet's Future

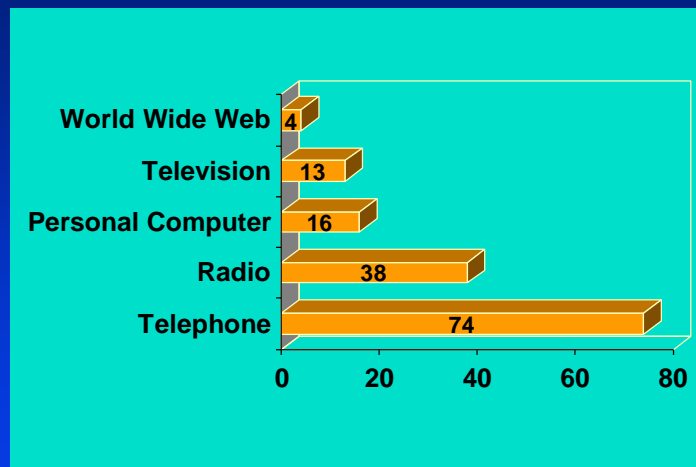- **Next Generation Internet legislation - Feb. 97**

- **Motivating Vision:**

  "In the 21st century, the Internet will provide a powerful and versatile environment for business, education, culture, and entertainment. Sight, sound, and even touch will be integrated through powerful computers, displays, and networks. ... Benefits of this environment will include a more agile economy, a greater choice of places to live or work, easy access to life-long learning, and better opportunity to participate in the community, in the nation, and in the world."

MCI Voice vs Internet: 1996-2001
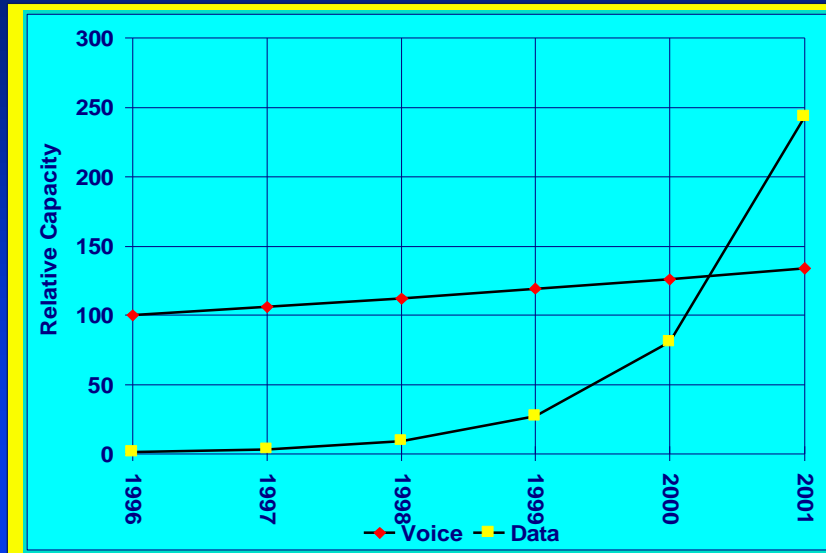
Internet Growth Has Been Little Short of Phenomenal….

Years it took to reach 50 million users

Source: ITU

Next Generation Internet Initiative

GOALS	METRICS
• **Connect universities, national labs, and research institutions with high-performance networks:**	**end-to-end performance; number of institutions connected**
– **1.1 At least 100 organizations at speeds of 100 times today's Internet**	
– **1.2 At least 10 organizations at speeds of 1000 times today's Internet**	
• **Promote experimentation with the next generation of networking technologies**	**quality of service; adoption of technologies by commercial Internet**
• **Demonstrate new applications that meet important national goals and missions**	**100+ high importance applications; value of applications in testing network technologies**

NGI Deliverables

- **100+ site high-performance testbed providing OC-3 connections over OC-12 infrastructure** — **1999**
- **Federal-academic-industry partnerships conducting applications/networking research** — **1999-2000**
- **10+ site ultra-high performance t[...] OC-48 connections**
- **Partnerships conducting network[...] research on ultra-high performan[...]**
- **Tested models for NGI protocols[...] quality of service provisions, sec[...] services**
- **Full goal of 100+ high value applications testing and benefiting from high-performance testbed** — **1999-2000**
- **Full goal of 10+ advanced applications testing and benefiting from ultra-high performance testbed** — **2001-2002**

OC = Optical Carrier

OC-3 = 155 Mbit/sec

OC-12 = 620 Mbit/sec

OC-48 = 2.48 Gbit/sec

OC-192 = 10 Gbit/sec

OC-3 = 155 Mbit/sec

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Academic Institutions and the Future of the Internet

- **Informal consortium formed by research universities in 1997**
- **Initially known by the name Internet-2 (I-2)**
- **Use very high speed Backbone Network System (vBNS)**
  - **NSF/MCI network for supercomputer centers**
- **Subsequent Qwest/Cisco/NorTel partnership: Abilene**
- **Major upgrades to campus networks required**
- **NSF Connections Grant Program**
- **1998 incorporation of I-2 as University Consortium for Advanced Internet Development (UCAID)**
  - **see http://www.ucaid.org/**

"Information Technology Research: Investing in Our Future"

**Final Report of the
President's Information Technology
Advisory Committee**

Submitted February 24, 1999

Report available at http://www.ccic.gov

Summary of PITAC's Report

- **Increase the Federal IT R&D Investment by approximately 1.4 billion dollars per year by 2004**
    - **Ramp up over five years**
    - **Focus on increasing fundamental research**
- **Invest in Key Areas Needing Attention**
    - **Software**
    - **Scalable Information Infrastructure**
    - **High-End Computing**
    - **Socioeconomic Issues**
- **Develop a Coherent Management Strategy**

PITAC's Proposed Increases for IT

Recommended funding increases for IT R&D for fiscal years 2000-2004

Area	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
Software	112	268	376	472	540
SII	60	120	180	240	300
High End Research	180	205	240	270	300
High End Acquisitions	90	100	110	120	130
Socioeconomic	30	40	70	90	100
Total	472	733	976	1192	1370

-in addition to the programs in existence in FY99

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Principal Finding

- **Underinvestment in Long-Term Fundamental Research**
  - **Agencies pressed by the growth of IT needs**
    - » **IT R&D budgets have grown, but not dramatically**
    - » **IT industry has accounted for over 30 percent of the real GDP growth over the past five years**
    - » **IT industry gets only 1 out of 75 Federal R&D dollars**
    - » **Problems solved by IT are critical to the nation**
  - **Most IT R&D agencies are mission-oriented**
- **This Trend Must Be Reversed**
  - **Need to ensure the continued flow of ideas to fuel the information economy and society**

Applications of IT Research

Findings:

- **Research investment in IT in "mission agencies" constrained by desire for short-term payoffs**
- **Failure to appreciate the ways in which basic research in IT can enable long-term agency goals**

Recommendations:

- **Encourage investment in enabling information technologies by research agencies**
- **Fund basic IT R&D in mission agencies, with agenda driven by long-term mission goals**

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National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

National Research Council

Computer Science and Telecommunications Board

David D. Clark, Chairman
Marjory S. Blumenthal, Executive Director

http://www.cstb.org

Enhancing the Internet for Health and Biomedical Applications

Technical Requirements and Implementation Strategies

This project will define technical capabilities that the Internet must provide in order to support a variety of medical applications. It will identify likely health care applications of the Internet; examine their demands for such characteristics as bandwidth, quality of service, security, and access; and recommend an appropriate strategy for implementing these capabilities in future instantiations of the Internet. An attempt will be made to distinguish those capabilities that are unique to health care applications from those more generally demanded of the Internet.

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Some Definitions

- *Bandwidth*: rate of transmission through a network
- *Latency*: time required to transmit data across the network (delay between time when a message is sent and received)
- *Availability*: "up time" of the network, including its individual links and services
- *Security*: composed of availability, confidentiality, and integrity considerations; ability to keep data from being maliciously or inadvertently lost or altered
- *Ubiquity*: a metric for the number and kinds of end users that a network can interconnect

Applications

- **Requirements: Not unique**
  - Possibly a unique set of complexities
  - Rapid changes in topology of organization
- **Six Major application areas**
  - Clinical Care
  - Consumer Health
  - Administrative and financial transactions
  - Public Health
  - Professional Education
  - Biomedical Research

Courtesy of Isaac Kohane

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Two Current High-End Examples

- **In the present, using current technology**
- **Large at the scale of <u>number</u> of transactions**
  - **Medline**
- **Large at the scale of individual transactions**
  - **Teleradiology**
- **The issue: Point-to-point vs. aggregate bandwidth**

Courtesy of Isaac Kohane

On-line Databases for the Biomedical Research Community

Database	Contents
MedLine	Indexes the entire biomedical serial literature. Contains basic reference information since 1966, and limited full text reference information from the National Library of Medicine. Contains more than 9,000,000 references from a list of 3,900 periodicals
GENBANK	database of DNA sequences (GENBANK)
SWISS-PROT and PIR	database of protein sequences
Protein Data Base, PDB	three-dimensional macromolecular structures
OMIM	stores information about human genetic diseases

Courtesy of Isaac Kohane

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Size of Some Common Medical Images

Image Type	Image Size (bits)	Images per exam	Size of one exam
Nuclear Medicine	128 x 128 x 12	30-60	1-2 MB
Magnetic Resonance Imaging	256 x 256 x 12	60	8 MB
Ultrasound	512 x 512 x 8(24)	20-230	5-60 MB
Digital Angiography	512 x 512 x 8	15-40	4-10 MB
Digitized electron microscopy	512 x 512 x 8	1	0.26 MB
Digitized Color Microscopy	512 x 512 x 24	1	0.79 MB
Computed Tomography	512 x 512 x 12	40	20 MB
Computed Radiograph	2048 x 2048 x12	2	16 MB
Digitized X-rays	2048 x 2048 x 12	2	16 MB
Digitized Mammography	4096 x 4096 x 12	4	128 MB

SOURCE: H.K. Huang, "Teleradiology Technologies and Some Service Models," *Computerized Medical Imaging and Graphics* 20(2), pp. 59-68.

Courtesy of Isaac Kohane

Desired Turn-Around Times for Different Types of Teleradiology

Type of Teleradiology Service	Turn-around time	Comments
Telediagnosis	4-24 hours	Exam at remote site: images and related information transmitted to expert center for diagnosis
Teleconsultation	30 minutes	Patient may still be waiting in the physician's office or exam room; a second opinion or diagnosis is sought.
Telemanagement	30 minutes	Immediate diagnosis required for a primary care physician to manage a patient in situ. Patient may be on the exam table

- **Urgency**
- **Synchronous vs. asynchronous needs**

SOURCE: H.K. Huang, "Teleradiology Technologies and Some Service Models," *Computerized Medical Imaging and Graphics* 20(2), pp. 59-68.

Courtesy of Isaac Kohane

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Findings

- **Internet today fails to meet needs of many health care applications:**
  - **QoS**
  - **Security**
  - **Reliability/availability**
  - **Ubiquity of high-speed access**
- **Private networks heavily used**
  - **some mature networked health care applications (e.g. mammography, telemedicine)**

Courtesy of Bruce Davie

Why Not Private Networks?

- **Cost**
- **Large investment by medical personnel to build/manage network**
- **Virtual private networks address these somewhat, but….**
- **Not conducive to dynamic creation of relationships**
  - **decentralized nature of (U.S.) healthcare demands this**
- **Well suited for some applications (e.g., record transfer within a provider)**

Courtesy of Bruce Davie

Unique Requirements?

- **Hard to argue that healthcare is unique**
  - **QoS: if ubiquitous, medium quality video conferencing worked on the Internet, it would be enormously valuable to health care**
  - **Lots of other industries would like this sort of QoS too**
  - **Moving a mammography study (~160 GB) in 2 seconds would require high bandwidth and low latency -- but it is not clear that this is ever needed**

Courtesy of Bruce Davie

QoS Requirements

- **Highly variable bandwidth requirements**
  - **e.g., rural health office needs could range from 0 to 5 Mbps**
- **Tight latency is the exception (e.g., remote instrument control)**
- **Scalability**
- **QoS policy and "emergency use"**
- **Not clear that current efforts are on track to meet these needs**

Courtesy of Bruce Davie

Unique Requirements? (cont.)

- **Security - are requirements different than e-commerce?**
  - **leaking results of an HIV test worse than disclosing a credit card number**
- **Need to create security associations on the fly, e.g., ER doc accessing patient record**
- **Existing models are flawed:**
  - **E-commerce uses server certificates and user passwords**
  - **weak authentication of user**
  - **time-consuming, hard to manage**

Courtesy of Bruce Davie

Security Requirements

- **Public Key Infrastructure (PKI) would be enormously valuable**
  - **Public keys issued to all healthcare participants**
  - **Some form of "certification hierarchy" (or a global authority) needed**
- **Role-based access to patient records**
- **Digital rights management**

Courtesy of Bruce Davie

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Ubiquitous Access

- **If income should not determine quality of care, ubiquity is needed**
- **Internet access *per se* is getting close to ubiquitous**
  - **"Free" PCs, internet appliances, kiosks**
- **What chance of ubiquitous access above 28.8 kbps?**
  - **Ever tried to get DSL/Cable modem in a remote rural area?**

Courtesy of Bruce Davie

Reliability & Availability

- **Anyone for Internet telesurgery?**
- **Many health care applications are intolerant of interruption (e.g., monitoring, device control)**
- **Perhaps there is more to this than non-crashing routers**
  - **Routing convergence times/fast re-route mechanisms**
  - **Prioritization/preemption of traffic**
  - **Robust QoS mechanisms**

Courtesy of Bruce Davie

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The Internet Research Agenda

- **Most of the issues raised here are known to the networking community**
- **The issue is one of priorities and fine-tuning**
- **Design decisions get made with an application in mind**
  - **e.g., QoS mechanisms for multiparty videoconferences may not be ideal for remote instrument control**
  - **Health care applications are rarely in the picture today**

Courtesy of Bruce Davie

More Findings

- **While health care could benefit greatly from Internet technology, level of involvement of health care agencies and industry in Internet R&D is small**
  - **compare to defense, e-commerce, automotive industry**
  - **reduced chance that specific health care needs will be met -- other industries are setting the priorities & optimizing solutions**
- **Health care is a late adopter**
- **Many organizational and policy issues impede progress**

Courtesy of Bruce Davie

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Observations Regarding Health Care Sector

- **Health care agencies are being encouraged to start funding application-driven networking research**

- **Health care can leverage much current networking research, but will fare much better with active involvement with the IETF and research community**

Courtesy of Bruce Davie

Public Policy Issues

- **Protection of Personal Health Information**

- **Access to the Information Infrastructure**

- **Intellectual Property Protection**

- **Regulations Affecting Electronic Delivery of Health Services**

- **Federal Leadership in Health Informatics**

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Summary

"Without deliberate, sustained action, the fundamental conflicts represented in these policy areas will keep the Internet from fulfilling its promise in health care."

"Networking Health: Prescriptions for the Internet"

- **Full report, with recommendations, will be released by the National Academies in a few weeks**
- **Watch the CSTB web site for information about the final report:**
    http://www.cstb.org/
- **Full report, in book format, will be available from the National Academies Press:**
    http://www.nap.org/

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